

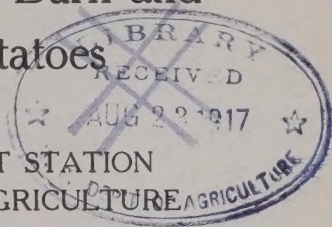
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Bordeaux Spray for Tip Burn and Early Blight of Potatoes

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HORTICULTURE AND FORESTRY SECTION

TRUCK CROPS



Ames, Iowa

SUMMARY

In the light of the data accumulated from five seasons of potato spraying with bordeaux mixture in Iowa, the following tentative conclusions may be drawn:

Tip burn and early blight are the two very common foliage troubles of the potato in Iowa.

Tip burn usually makes its first appearance early in July. Early blight usually comes a month later.

Tip burn is caused by the leaves giving off moisture faster than the roots can supply it. This condition is induced by high temperatures combined with low humidity.

Early blight is favored by the advent of cool fall weather and is then most likely to become serious.

Three applications of bordeaux mixture gave an average annual increase of 10 bushels per acre; five applications, 20 bushels per acre and seven applications, twenty-two bushels per acre for the five years.

Five applications are most profitable and gave an increase in yield of 17 per cent.

Three applications are not sufficient and seven applications represent a diminishing net return.

Seven applications increase the yield slightly but there is not much increase in the amount of tubers of marketable size.

On the basis of five applications, the first bordeaux spray should be applied for tip burn and early blight early in July and repeated at approximately ten day intervals.

BORDEAUX SPRAY FOR TIP BURN AND EARLY BLIGHT OF POTATOES

BY A. T. ERWIN*

Tip burn and early blight, the two most common foliage troubles of the potato in Iowa, are of enough economic importance in the corn belt to be dealt with profitably thru the use of the bordeaux spray. Five seasons of spraying experiments at the Iowa Agricultural Experiment station point to that conclusion. These tests also suggest that under Iowa conditions five applications of bordeaux mixture per season are likely to be most profitable. That number gave an average annual crop increase of 20 bushels of potatoes per acre and an average annual increased profit of \$9.62 per acre. Three applications gave an average annual increase of only 10 bushels per acre and an average annual increased profit of only \$2.07 per acre, which seemed too little to be profitable. Seven applications gave an average annual increase of 22 bushels per acre in the yield and of \$5.96 in profit, representing a diminishing net return.

PURPOSE AND PLAN OF EXPERIMENT

The experiments dealing with tip burn and early blight were inaugurated in 1911 and continued annually to meet the very specific question of growers whether under corn belt conditions these troubles can be dealt with profitably by bordeaux spraying. The two troubles were considered together in the experiment because tip burn nearly always accompanies early blight and because bordeaux mixture is recommended as a specific for both. The possibility of controlling both troubles with bordeaux applications had already been well established and was not considered in this experiment. The problem was further simplified by the fact that late blight, which is common in the northern states where extensive potato spraying experiments have been conducted, is of rare occurrence in Iowa.

In Iowa the climatic conditions under which early potatoes mature differ widely from those under which the late crop ripens. This is also true with reference to the development of tip burn and early blight on the early and late crops. Therefore the two crops were treated separately and the experiment here reported

* Acknowledgement is due to Dr. I. E. Melhus for helpful suggestions and for specimens from the plant pathology museum from which the drawings of early blight and tip burn were made.

deals only with late potatoes. The variety, Rural New Yorker, was selected for the work because it is the leading late variety thruout the state.

Plots containing one-fifth of an acre each with check plots alternating were planted on the black Wisconsin drift soil on the station farm at Ames. The total yield from the entire plot rather than a select number of hills was measured in computing yields. The grading was done with a machine grader on a $1\frac{3}{4}$ inch screen. All tubers which passed thru this size opening were classed as culls. This is a larger screen than that used by many growers and in dry seasons the percent of culls was heavier than many growers figure.

APPLYING THE BORDEAUX MIXTURE

The first application was made on the different plots the second week in June. Later applications continued at regular intervals, according to the number required by the plan of the experiment, until the last of August each year.

The bordeaux mixture used consisted of 5 pounds copper sulfate, 5 pounds lime, and 50 gallons of water or what is commonly designated as the 5-5-50 formula.

COST OF SPRAYING POTATOES

The cost of spraying is figured at 96 cents per acre for one application thruout the experiment. These figures are computed on the following basis which represent approximately the average cost for the five years preceding the war.

Copper sulfate @ 6 cents lb.

Lime, @ 1 cent lb.

Man and team hire, \$4 per day.

Area sprayed per day with 4-row traction sprayer, 10 acres.

Formula used, 5-5-50.

Rate of application 80 gallons per acre.

Summary of acre cost—

8 lbs. copper sulfate,	.48 cents
8 lbs. lime,	.08 cents
1 hour man and team time,	.40 cents

Total cost to apply 1 application for 1 acre,	.96 cents
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The spraying pressure averaged approximately 180 pounds. At this pressure, more effective work can be done and less material is required than with the low pressure obtained with hand pumps. The water supply tanks and spray materials were immediately adjacent to the field, hence there was but little loss of time on the road. Stock solutions of spray materials were made up in advance thus facilitating the work.

FIVE YEARS' RESULTS OF BORDEAUX SPRAYING

The following tables and charts give the results of the five years of bordeaux spraying for tip burn and early blight:

TABLE I. AVERAGE ACRE YIELD WITH BORDEAUX SPRAYING
Summary for Five Year Period. Variety—Rural New Yorker

No. of Applications	Total yields per acre	Marketable yield per acre	Culls per acre	Per cent culls	Bushels per acre increase from spraying
3 -----	130.2 bu.	114.3 bu.	15.9 bu.	12.2	10.4
5 -----	139.1	120.9	18.2	13.1	17.0
7 -----	142.1	121.5	20.6	14.5	17.6
Check -----	120.9	103.9	17.0	14.1	

TABLE II. TOTAL YIELD PER ACRE BY YEARS, WITH BORDEAUX SPRAYING. Variety—Rural New Yorker

No. of applications	Year 1911	Year 1912	Year 1914	Year 1915	Year 1916	5 year average
3 -----	97.2 bu.	101.0 bu.	75.6 bu.	234.2 bu.	143.1 bu.	130.2 bu.
5 -----	109.6	104.4	80.3	229.5	171.7	139.1
7 -----	111.1	136.2	97.5	201.2	164.7	142.1
Check ---	74.8	98.8	72.8	213.7	144.6	120.9

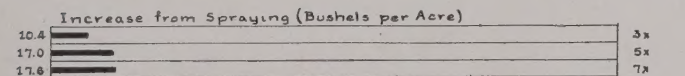
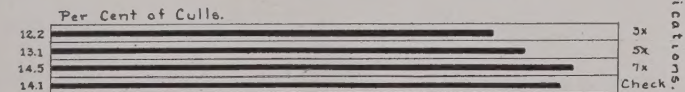
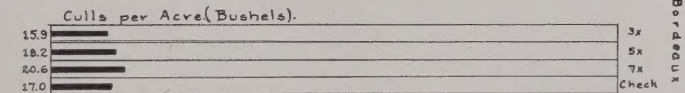
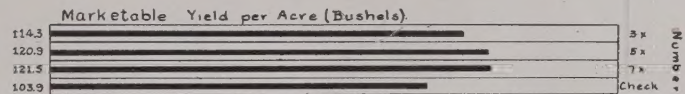
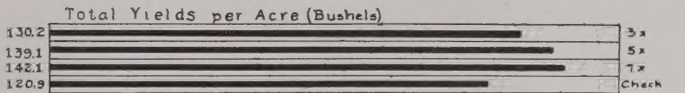


Chart I. Showing relative average yield per acre for 5 years with spraying and without.

TABLE III. YIELD FOR EACH YEAR AND THE PROPORTION OF
MARKETABLE TUBERS AND PERCENTAGE OF CULLS
WITH BORDEAUX SPRAYING

1911*

No. of applications	Total yield per acre	Marketable yield per acre	Culls	Per cent culls
3 -----	97.2 bu.	87.9 bu.	9.3 bu.	9.6
5 -----	109.6	103.8	5.8	5.3
7 -----	111.1	101.4	9.6	8.6
Check -----	74.8	66.9	7.9	10.6

1912*

No. of applications	Total yield per acre	Marketable yield per acre	Culls	Per cent culls
3 -----	101 bu.	91.5 bu.	9.5 bu.	9.4
5 -----	104.4	96.1	8.3	8.0
7 -----	136.2	128.6	7.6	5.6
Check -----	98.8	95	3.8	3.8

1914

No. of applications	Total yield	Marketable yield per acre	Culls	Per cent culls
3 -----	75.6 bu.	65 bu.	10.6 bu.	14.0
5 -----	80.3	59.8	20.5	25.5
7 -----	97.5	66.7	30.8	30.5
Check -----	72.8	50.4	22.4	30.8

1915

No. of applications	Total yield	Marketable yield per acre	Culls	Per cent culls
3 -----	234.2 bu.	222.5 bu.	11.7 bu.	5.0
5 -----	229.5	218.7	10.8	4.3
7 -----	201.2	190.6	10.6	5.3
Check -----	213.7	200.5	13.2	6.2

1916

No. of applications	Total yield	Marketable yield per acre	Culls	Per cent culls
3 -----	143.1 bu.	104.5 bu.	38.6 bu.	27.0
5 -----	171.7	125.9	45.8	26.7
7 -----	164.7	120.5	44.2	36.7
Check -----	144.6	106.9	37.7	26.1

* Both the check and bordeaux plots were protected against insect injury by two arsenical applications, the cost of which is not figured as the plots were all on the same basis in this regard.

* Under the direction of L. Greene and T. J. Maney for the years 1911 and 1912.

TABLE IV. AVERAGE ANNUAL CROP VALUE FOR FIVE YEAR BORDEAUX EXPERIMENT — LATE POTATOES

No. of Bordeaux applications*	Gross value per acre	Net value per acre after deducting cost of spraying	Net profits per acre from spraying	Percent gain from spraying
3 -----	\$88.00	\$85.12	\$2.07	2.43
5 -----	97.47	92.67	9.62	10.38
7 -----	95.73	89.01	5.96	6.70
Check -----	83.05	83.05		

TABLE V. VALUE OF POTATOES PER ACRE FOR EACH YEAR WITH BORDEAUX SPRAYING

No. of applications	Year 1911	Year 1912	Year 1914	Year 1915	Year 1916
3 times					
Gross value per acre---	@ 71c* bu.	@ 44c bu.	@ 58c bu.	@ 53c bu.	@ 1.75 bu.
	\$62.41	\$40.26	\$37.70	\$117.66	\$182.00
Cost to spray-----	2.88	2.88	2.88	2.88	2.88
Net -----	59.53	37.38	34.82	114.78	179.12
5 times					
Gross value per acre---	73.70	42.28	34.80	116.07	220.50
Cost to spray-----	4.80	4.80	4.80	4.80	4.80
Net -----	68.90	37.48	30.00	111.27	215.70
7 times					
Gross value per acre---	71.99	56.58	38.86	101.23	210.00
Cost to spray-----	6.72	6.72	6.72	6.72	6.72
Net -----	65.27	49.86	32.14	94.51	203.28
Check					
Lead arsenate only----	47.50	41.80	29.00	109.71	187.25
Net -----	47.50	41.80	29.00	109.71	187.25

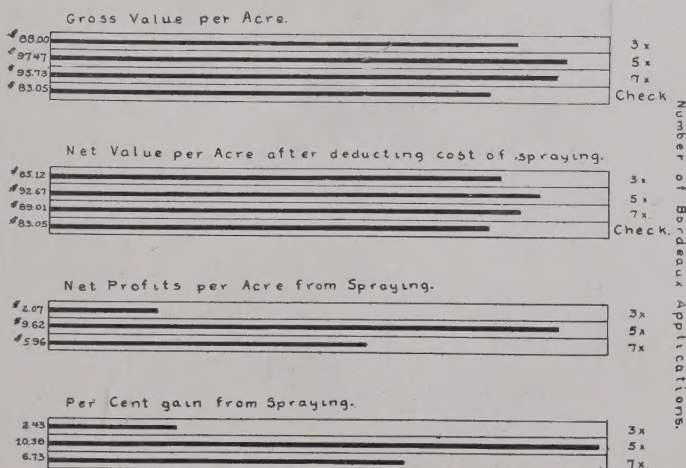


Chart II. Showing relative crop value per acre for 5 years, with and without spraying.

* Prices throughout are based upon December 1st farm value. Iowa Year Book 1915—687 a.

EARLY BLIGHT (*Alternaria Solani*)

Early blight is a fungus spot disease which may attack both living and dead tissue. When it works on living leaves it is called a parasite and when on dead tissue it is said to be a saprophyte.

Under Iowa conditions, early blight usually makes its first appearance as a saprophyte following tip burn injury. Early on a dewy morning, or following a shower in a cool spell, a brown mould may be observed on the dead tissue. This represents the summer fruiting spores of the saprophytic form.

Under favorable conditions the parasitic form of early blight invades the live tissue, causing the appearance of dark brown, irregular spots, with characteristic, irregular ridged lines, concentrically arranged. (See fig. 1). As these spots become enlarged they unite, forming larger areas until a considerable proportion of the leaf may become involved. The disease affects foliage and stems, but not the tubers as in the case of late blight. However, its economic importance should not be lessened on this account. The potato plant is dependent upon the foliage for the process of assimilation, hence, it can do its best work only when provided with a sound, healthy leaf system.

Early blight also often gains entrance thru flea beetle injury. As this insect is very generally present in the potato fields, it no doubt does much to facilitate early blight infection. To this extent any steps looking to the control of this insect serves indirectly in checking the spread of the disease. Jones¹ found that spraying with bordeaux mixture reduced flea beetle injury 50 percent. However, as an insecticide for flea beetles, bordeaux mixture is not equal to lead arsenate.

TIME OF APPEARANCE

Early blight flourishes during a cool season and does not commonly appear in central Iowa until past midsummer. In the cooler parts of the United States it usually appears earlier than this and also in advance of late blight, hence, the term early blight. Under corn belt conditions the term is really a misnomer but is adhered to for the purpose of avoiding confusion because it has been so widely used in potato literature.

In Wisconsin, Vaughan reports in a letter to the author that it is generally first noticed in central Wisconsin on the early crop between June 20 and July 10. Milward² says that it rarely becomes serious over the state until after the middle of August. Tolaas reports by letter that early blight commonly makes its first appearance in Minnesota in the region of St. Paul about the middle of July.

¹ Bull. Vt. Agrl. Exp. Sta. 159: 244.

² Ann. Rep. Wis. Agrl. Exp. Sta. 24: 346.



C.W. Redwood.



C.W. Redwood.

Its first appearance at Ames in 1916 was reported by Melhus, Iowa Agricultural Experiment station pathologist, on September 7. This year was unusually dry and hot, which probably delayed its development. The year, 1915, was quite the reverse. The season was cold and wet and the disease was common by the latter part of July. Under average conditions it may be expected any time after the middle of August in central Iowa.

Unlike late blight, early blight is comparatively slow in development. The mycelium can often be found in the vines two to three weeks in advance of its appearance. Tho present, it is held in check by high temperatures and low humidity. With the advent of the cool fall weather and heavy dews its growth is encouraged.

SUSCEPTIBILITY OF VARIETIES TO EARLY BLIGHT

Eastern authorities report that the early varieties of potatoes are particularly susceptible to early blight injury. Under Iowa conditions this has not proven to be the case for the reason that early varieties of potatoes, if planted early, are well on towards maturity before early blight becomes prevalent. Generally speaking, the early varieties, particularly the Early Ohio, which is widely planted here, have a poorer foliage and a weaker constitution than the late sorts. If the disease attacked them at the same stage of their development, because of late planting, at which it attacks the late kinds, the early varieties would probably be affected much as they are in the east.

TIP BURN

Tip burn is caused by too rapid loss of water from the leaves and results in the collapse and death of the marginal cells of the leaf as indicated in fig. 2. Under conditions of extreme heat and a dry atmosphere the foliage moisture is carried off faster than it can be replaced by the root system and tip burn results. That this injury is thus brought on is evidenced by the fact that plants shaded by a tree are less affected. In this case the average soil moisture supply is less than in the open, but the foliage is protected from excessive transpiration by sun and wind.

The first indications of tip burn injury are a wilting of the foliage and an upward rolling of the leaves. Later the margin and tips show a withered appearance and begin to dry up, finally becoming brown, giving the typical "burn" appearance. It is not a fungous trouble and is wholly physiological in character.

The influence of climatic factors upon tip burn was strikingly illustrated in the seasons of 1914-15-16. In 1915 it was abnormally cool³ and wet. The potato foliage, up to the outbreak of late blight, was remarkably luxuriant and with practically no

³ Bull. Ia. Agrl. Exp. Sta. 163: 291.

tip burn. The field conditions in the seasons of 1914 and 1916 represented the other extreme. High temperatures and deficient rainfall characterized the months of July and August in both years and tip burn was very abundant. In fact, a perfect leaf was a rare exception on the mature foliage.

The direct loss in potato yields due to tip burn is without doubt serious. The main business of the potato plant during the last half of its growth period is that of storing up starch in the new tuber. In this work the leaf system takes a leading part. Any impairment of the foliage at this stage of the plant's development cannot be other than critical.

Lutman⁴ estimates that in the state of Vermont, where the climatic conditions are less favorable for tip burn than in Iowa, that at least two-thirds of the injury to late potato varieties, other than that wrought by fungus or bacterial attack, is due to tip burn. The remainder of the injury is due to flea beetles.

Flea beetle injury intensifies the trouble. Often around each puncture there is a burnt marginal area due to the fact that when the leaves are whipped by the wind, portions of the dead tissue fall away, leaving a ragged irregular outline.

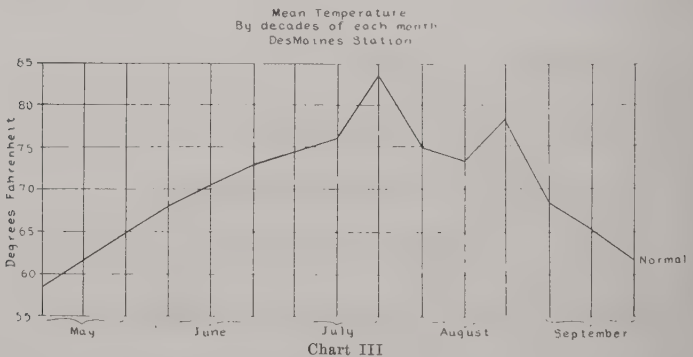
CLIMATIC CONDITIONS WHICH CAUSE TIP BURN

A study of the climate for the summer months presents some important facts as to the cause of tip burn in Iowa and the conditions under which it occurs.

The important factors affecting transpiration, or the giving off of moisture by leaves, are temperature, rainfall, humidity, and sunshine.

THE TEMPERATURE RELATION

In chart III are shown the normal maximum temperatures⁵ for the growing season of the potato in Iowa. It will be noted



⁴ Bull. Vt. Agr. Exp. Sta. 196: 4.

⁵ U. S. Weather Bureau, Des Moines Station.

that the temperature for June is relatively low and that the high temperatures for the summer are reached during the third decade of July.

HUMIDITY

A study of humidity, chart IV, indicates a condition the reverse to that of temperature. The low point for the summer is reached during the second decade of July from which time there is a gradual rise to the end of the season.

Per Cent of Humidity
By decades of each month
Des Moines Station



Chart IV

SUNSHINE

The percent of possible sunshine, chart V, is relatively low for May and September and reaches its maximum during the second decade of July.

Per Cent of Possible Sunshine
By decades of each month
Des Moines Station



Chart V

RAINFALL

The rainfall, chart VI, is heaviest during the period covered by the third decade of May and the month of June. July and

Rainfall
By decades of each month
Des Moines Station

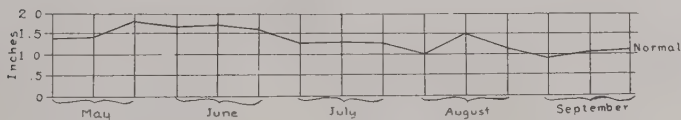


Chart VI

September are relatively dry months with a decided increase in precipitation during the second decade of August.

It will therefore be noted that July and early August present a serious combination of unfavorable climatic factors for the potato. This period is characterized by low humidity, scant rainfall and high temperatures.

The ability of the plant to withstand adversities is in a measure determined by its previous condition. The climate for the month of June, from the standpoint of humidity, rainfall and temperature, is such as to induce a vigorous, sappy growth. Hence the plant is ill prepared for the dry hot weather and low humidity of July and early August. The giving off of moisture is in excess of root absorption during this period. As a result, the marginal leaf cells collapse and die, producing tip burn.

Under normal conditions the soil is liberally stored with moisture in June. A dry soil intensifies the trouble but is not primarily responsible for it. Tip burn is mainly a question of the air being too dry and of the leaf being robbed of its moisture, rather than of the lack of soil moisture.

The structure of the potato leaf, as has been pointed out by Fitch,⁶ makes it particularly susceptible to injury under unfavorable climatic conditions. The leaf cells are loosely arranged and the stomata are so exposed as to make it difficult for the plant to protect itself against excessive loss of moisture.

SUSCEPTIBILITY OF VARIETIES

The three varieties most widely grown in Iowa are Early Ohio, Rural New Yorker, and Irish Cobbler. When subjected to tip burn under comparable conditions at the same stage of growth, Early Ohio shows the greatest degree of injury, the Rural the least, and the Irish Cobbler ranks between the two.

The conditions were unusually favorable in 1916 for tip burn. Under the extreme heat and prolonged drought of July and August, many varieties collapsed and ripened off a crop of small tubers. The variety Rural New Yorker made a remarkable showing under these conditions. The general average of its foliage condition was the best of all the varieties and the plants made the best recovery of any of the varieties when the rains and cool weather finally came on. This variety possesses a rather small, thick, rugose leaf which is very much in its favor for the corn belt conditions.

Of all the varieties grown on the Iowa Agricultural Experiment station grounds, the Rural New Yorker has proven outstanding in its heat endurance and ability to recover when the fall rains come on.

⁶ Bull. Colo. Agrl. Exp. Sta., 216: 14.

BORDEAUX AS A PREVENTIVE OF TIP BURN

Aside from its properties as a fungicide, important claims have been made for bordeaux as a preventive of tip burn. Lutman⁷ in discussing the use of bordeaux in seasons in which fungous troubles are not present says "Bordeaux mixture increases the yield from potato plants by the prevention of tip burn and flea beetle injury. When plants which are not troubled by tip burn or flea beetle are sprayed, yields are not increased." Similarly, beneficial results from the use of bordeaux in preventing tip burn are reported by Stewart⁸ of the New York Agricultural Experiment station.

The general trend of field evidence under eastern conditions strongly indicates the value of bordeaux for this purpose and also as a stimulant causing greener and more luxuriant growth of foliage.

On the other hand, laboratory studies seem clearly to indicate that bordeaux applications actually increase transpiration. Thus spraying might seem to have a tendency to increase rather than check tip burn and its use in regions of a dry atmosphere where tip burn is normally severe might prove a detriment rather than a benefit.

Duggar and Cooley⁹ found that a film of bordeaux facilitates transpiration.

Martin¹⁰ reports that "in every instance the sprayed leaves showed signs of wilting at some period preceding the time at which the unsprayed leaves of the same species began to wilt. This is only what would be expected in view of the fact that the average rate of water loss from the sprayed leaves is nearly double that from the unsprayed leaves during the experimental time period." Martin¹¹ also found that the influence of bordeaux mixture on the rate of transpiration becomes effective immediately after the spray dries on the leaves. The highest average increase occurs during the first two hour period following an application of the spray.

Thus on the one hand we have the field evidence under eastern conditions favoring the use of bordeaux mixture to prevent tip burn and the experiments of the laboratory on the other leading to a contrary conclusion.

In the period of the Iowa experiments, the foliage conditions on the sprayed and unsprayed plots were carefully studied. On the one hand the use of bordeaux mixture did not show the marked results as a specific for tip burn that followed its use

⁷ Bull. Vt. Agrl. Exp. Sta., 196: 4.

⁸ Bull. N. Y. Agrl. Exp. Sta., 311: 37.

⁹ Mo. Bot. Gard., 1: 1-22; 351-356.

¹⁰ Journ. Agrl. Res., 8: 536.

¹¹ Journ. Agrl. Res., 7: 529.

in the above mentioned experiments in eastern states. On the other hand, at no time was there evidence that it increased tip burn, or was otherwise injurious. In other words, under corn-belt conditions, bordeaux spraying is not the positive factor that it has proven to be under other conditions.

Accepting Martin's figures of an accelerated period of two hours following spraying during which transpiration was greatest, we have a total of ten hours on a basis of five applications. This is spread over an interval of eight to ten weeks. Under Iowa's high temperatures and low humidity, the bordeaux film becomes dry much quicker in the field than under laboratory conditions, which would shorten this accelerated period. On the whole, we have seen nothing in the way of field evidence to suggest that bordeaux increases tip burn.

In general, we were not able to see that the foliage conditions averaged either better or worse between the plots receiving seven applications and those not sprayed at all. On different occasions we had the labels covered and submitted the plots to review by other, none of whom was able to distinguish consistently between the sprayed and unsprayed nor between the plot receiving three and the one receiving seven applications.

Apparently under our climatic conditions the plant does not respond to this stimulant to the degree that it does in cooler and more humid climates.

BORDEAUX AS A PLANT STIMULANT

Aside from its value in the control of diseases, bordeaux has been found useful as a plant stimulant.

Lutman¹² summarizes the general effects of bordeaux applications as follows:

1. Dark green color with increased chlorophyll content.
2. Thicker leaves and sturdier stalk.
3. Longer life—ten days to two weeks of the crop.

Stewart,¹³ in discussing the results for the year 1911 at the New York experiment station, says: "There was no late blight whatever, only a very little early blight and very little flea beetle injury. The unsprayed rows were affected by no disease of any consequence except tip burn and even of that there was only a moderate amount. . . yet spraying increased the yield at the rate of 93 bushels per acre. Plainly we have here a striking example of the beneficial influence of bordeaux in the absence of diseases and insect enemies."

At no time during the five years of the Iowa experiment has there been the clear cut and outstanding evidence of any marked

¹² Bull. Vt. Exp. Sta., 196: 58.

¹³ Ann. Mo. Bot. Gard., 1: 3.

physiological response from the use of bordeaux applications as indicated above. On the other hand, the difference in yield in favor of the sprayed plots indicates that there was a definite response from bordeaux applications. Where the tip burn was generally present and early blight practically absent, the yield was higher on the sprayed plots, indicating that the plant had been stimulated and benefited by the bordeaux applications.

The fact of the results being less marked than we had been led to anticipate from the New York and other experiments is probably due to our radically different climatic conditions. Iowa approaches the semi-arid region of the western plains. Its sunshine is more intense and its humidity lower than in the New England states. Heavy dews are also less frequent.

Moisture is an important factor in accelerating or retarding chemical activity. It is a common observation that bordeaux injury is most likely to appear when "muggy" weather immediately follows a spray application. Bain¹⁴ has shown that bordeaux applied to the under surface of a peach leaf, where it remains dry, is not injurious, while a similar application to the upper surface may severely scorch the foliage. Martin¹⁵ found that a surface covering of dry powdered copper sulfate was less effective in accelerating the rate of transpiration than was a surface film of bordeaux mixture. These and other similar results would lead us to expect bordeaux to become inert much more quickly in Iowa than in regions of higher humidity and to produce a lesser physiological response, and the field evidence points to this conclusion.

Lutman¹⁶ found in experiments conducted by him in the leading potato producing sections of Germany that bordeaux applications did not prove profitable except for the control of late blight. Clearly the climatic relationship is an important factor in the use of bordeaux.

It may also be noted that under corn belt conditions the potato produces a more sparse foliage than in the cooler regions further north. This in turn may affect the plant in its ability to respond to chemical stimuli.

¹⁴ Rept. Tenn. Agrl. Exp. Sta., **15**: 88.

¹⁵ Journ. Agrl. Res., **7**: 547.

¹⁶ Bull. Vt. Agrl., 196: 36.

